1972-12

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http://hdl.handle.net/10945/16233

LASER LIGHT ABSORPTION CHARACTERISTICS OF A LASER PRODUCED HYDROGEN PLASMA

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THESIS

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OF A LASER PRODUCED HYDROGEN PLASMA

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December 1972

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Laser Light Absorption Characteristics
of a Laser Produced Hydrogen Plasma

by

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN PHYSICS

from the

NAVAL POSTGRADUATE SCHOOL
December 1972

ABSTRACT

Light from a neodymium doped glass laser was focused in Hydrogen gas at pressures from 20 millitorr to 62 atmospheres in order to produce optical breakdown of the gas. In the cases where breakdown was experienced, absorption of the remainder of the laser pulse by the resulting plasma was studied. It was found that the hydrogen plasma had some very distinct absorption characteristics; in that, absorption was very small at pressures slightly exceeding the threshold for optical breakdown, and very strong at pressures above one atmosphere. There was strong evidence of a frequency shift greater than 35 angstroms of the laser light as a result of its transit through the plasma. Photographs of the forward transmitted laser intensity pulses after breakdown were compared in time with a similar pulse in which no breakdown was experienced. An effort was made to discover evidence of anomalous absorption at the plasma frequency near the frequency of the laser light. The data does not conclusively support anomalous absorption in the pressure range where the plasma frequency is approximately equal to the laser light frequency. There was evidence of increased absorption at lower pressures that might be a result of an anomalous heating mechanism.

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I. INTRODUCTION

The purpose of this study was to investigate the absorptive characteristics of a hydrogen plasma formed by focusing the light from a giant pulse neodymium laser in the presence of hydrogen gas. A more specific aim was to find evidence for the phenomenon of anomalous absorption in which increased absorption is induced by specific properties of the plasma. The laser light was focused by a simple double-convex lens in a pressure cell containing hydrogen gas at pressures from 20 millitors to 62 atmospheres. In the cases where breakdown was experienced, absorption of the remainder of the breakdown producing laser pulse by the resulting plasma was studied.

A straight-forward experiment was undertaken in which pressure of the hydrogen gas was varied in order that the plasma electron frequency equal the laser light frequency. For a given pressure the density of molecules of a gas can be calculated. The density of electrons associated with the neutral molecules is then twice the density of molecules in the case of hydrogen gas. Thereby, an upper limit of electron density after molecular disassociation, and ionization is fixed and quickly determined. The plasma electron frequency is a function of the square root of the electron density. A slightly modified form of the ideal gas law was incorporated to find the pressure necessary to yield

the proper electron density under equilibrium conditions. Special attention was devoted to pressures near the pressure predicted by the modified gas law.

II. THEORY

If a deuterium plasma is sufficiently heated to high temperatures, nuclear fusion is probable and a subsequent release of energy could be realized. Laser heating provides a possibility of achieving these temperatures. Instabilities in the plasma provide for increased absorption of laser radiation and heating of the plasma is thereby increased.

The primary absorption process for a fully ionized plasma is due to electron-ion collision. Energy is absorbed over a distance L by a plasma according to the equation

$$E = E_o(1-e^{-KL})$$

where E_o is the laser energy, and K is the absorption coefficient given given by the equation [Ref. 5]

$$K \doteq (8Z^2e^6n^2\ln\Lambda)/3c\nu^2(2\pi m_e kT)^{3/2}(1-\nu_p{}^2/\nu^2)^{1/2} .$$

According to Kaw [Ref. 2] the classical absorption length of a plasma when the plasma frequency is close to the laser light frequency is given by

$$L = 5 \times 10^{18}T^{3/2}/n_e \text{ microns}$$

where T is measured in eV and n_e in cm^{-1}. In a plasma of temperature 10^3 eV and density 10^{21} the classical absorption length is 1500 microns, and a typical plasma radius is approximately 100 microns. This situation will not allow sufficient heating to attain thermonuclear temperatures. As the plasma mentioned above expands in its reaction to a sudden increase in temperature, it becomes transparent to the laser light and consequently loses its ability to absorb more energy from the laser pulse. Another possibility is that the plasma will reflect the laser light when the laser light frequency is less than the plasma electron frequency. Again the plasma temperature is not increased, as there is no heating.

In a paper by Kaw, and others [Ref. 1], the authors present evidence of enhanced absorption based on computer simulations, laboratory experiments with microwaves, and on experiments involving radio wave propagation in the ionosphere. The evidence, according to the authors, establish the existence of anomalous heating beyond doubt. This anomalous heating is a result of moderate ion density fluctuations which give rise to strong enhancement of high frequency resistivity at frequencies in the vicinity of the plasma electron frequency. This enhancement in high frequency resistivity yields increased absorption.

In two separate works by Dawson, and Oberman [Ref. 3 and 4] a linear theory of high frequency resistivity is discussed. In this theory the electrons of the plasma are

treated as a fluid and the ions as relatively stationary potential spikes. A graph is shown where [Fig. 9] the resistivity of the plasma is a function of the ratio of the imposed background oscillating electric field to the plasma frequency. The curve shows that resistivity is a constant up to frequencies close to the plasma frequency. There is a slight rise in resistivity at frequencies close to the plasma frequency, and then a drop in resistivity at frequencies greater than 1.4 times the plasma frequency. This slight rise in resistivity at the plasma frequency is thought to be a result of the excitation of longitudinal plasma waves that are caused by an interaction between the oscillating electron fluid and the ion spike potentials. The background oscillating electric field drives the electron fluid in cyclic motion about the ion potentials, which exert perturbations on the fluid motion. When the frequency of the background oscillating electric field is close to the plasma frequency, the perturbations are at the frequency necessary to excite the natural modes of the electron fluid. If the ion potential spikes are randomly distributed, the perturbations will develop destructively interfering waves, and will be damped away. If the ions are distributed in order, the perturbations of the oscillating electron fluid will yield waves that will constructively interfere, and in this way the waves grow as a result of energy taken out of the background electric field.

The development of these waves is possible in the case of the regularly positioned ions in the plasma. The stronger the regularity, the greater the amount of energy transferred from the background field to these waves. Reference 2 predicts that the ion correlation can be strong as a result of an intense electric field near the electron plasma frequency. The authors suggest that the intense electric fields experienced in the beam of a giant pulsed laser might be sufficient to obtain strong ion correlation.

The electron plasma frequency is given by the equation

$$\nu_{pe} \doteq \frac{\omega_{pe}}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{n_e e^2}{m\varepsilon_o}} = 8.99 \times 10^3 \; n_e^{1/2}$$

where n_e is the electron density in cm^{-3}. The frequency of the neodymium laser is 2.81×10^{14} sec^{-1}. These two frequencies are set equal and the expression is solved for electron density. It was found that the electron density is given by

$$n_e = 9.76 \times 10^{20} \; cm^{-3}.$$

The ideal gas law is used to approximate the pressure of a gas under equilibrium conditions that has the necessary density.

$$\frac{P\,V}{T} = \frac{P_o\,V_o}{T_o}$$

At a pressure of one atmosphere, and temperature 273° Kelvin, a volume of 22.4 liters of a gas contains 6.023×10^{23} molecules. The equation above is modified to include density information.

$$\frac{P\,V}{T\,N} = \frac{P_o\,V_o}{T_o\,N_o}$$

P_o = 1 atm, V_o = 22.4 ltre, T_o = 273° K, and $N_o = 6.023 \times 10^{23}$. The equation is solved for pressure, and the N/V term is changed to a density term n. The result is:

$$P = 4.019 \times 10^{-20}\ n.$$

This pressure is in units of atmospheres when n is in units of cm^{-3}.

It is assumed that the plasmas produced in this study, with the neodymium laser operating at average powers of 300 MW, are 100% ionized within the focal volume of the lens used. It was further assumed that molecular disassociation occurred in each case of ionization. Incorporation of these two assumptions enables the direct substitution of the electron density in the equation. However, due to disassociation the pressure must now be reduced by a factor 1/2. When this is done the pressure of the gas is found to be

$$P = 19.62 \text{ atm} = 288.4 \text{ psia.}$$

The temperature of the room was used for the temperature of the neutral gas. On the average it was 22° C, and this value was used in the above calculations. In the experimental technique however, allowances were given for pressure gauge innaccuracies, and a range of pressures were studied. In this way it was felt that the 22° C temperature used above was not critical, but did provide a general region to be studied.

III. EXPERIMENTAL PROCEDURE

A. APPARATUS

A Korad Model K-1500 neodymium laser system was used throughout the study. Important characteristics of the system are:

Energy	3 to 9 Joules
Pulse width	22 to 28 nanoseconds
Peak power	250 to 350 Megawatts
Wavelength	1.06 micrometers
Beam diameter	0.75 inch

A pressure cell was designed to contain gas at pressures from 20 microns of mercury up to 62 atmospheres. The cell had a center cavity volume of approximately 12 cubic inches. It was outfitted with two inch diameter circular entrance and exit windows. Two side windows were two by three inch rectangular openings; top and bottom openings of the same dimensions were not used as windows, but were blocked off with plates of brass. All windows were of Pyrex 7913 tempered glass which has a 91% transmission characteristic at the laser wavelength. The top brass plate was fitted with the gas supply plumbing. A forepump was used to lower the pressure from one atmosphere. A supply of nitrogen purged the whole system. A method was worked out with the nitrogen supply and the forepump such that repeated flushings insured a relatively pure amount of hydrogen gas. Nitrogen

was used after the experimenting each day to clean out the system for safety considerations.

Three photodiode detectors were used in order to monitor the laser pulse before breakdown, to measure energy of the plasma radiation, and to monitor the forward transmitted light after breakdown. The pulse of the laser was detected before breakdown with a Korad K-D1 photodiode. It provided laser pulse intensity, and energy information. It also was a convenient trigger for the three oscilloscopes used. The forward transmitted light was detected by an ITT F-4000 S-1 photodiode which provided transmitted pulse intensity information. A Tropel Model 330 photodiode was utilized in order to obtain plasma radiation intensity and energy information. Figure one shows the relative physical layout of the system.

A helium neon laser also shown in Figure one provided a valuable alignment tool, which enabled the cell to be aligned with the neodymium laser beam. The light from this helium neon laser was allowed to pass through the system at all times as its very low power was not a factor in the measurement of the large light intensities experienced throughout the study. The pressure cell was aligned by placing aluminum discs with small holes centered in each in the window openings of the entrance and exit ports. The cell was situated on an adjustable table that could be adjusted in height and lateral angle. Adjustments were made such that the light from the helium neon laser passed through front and rear

holes. This procedure was followed rigorously the first time, and thereafter checked before work was begun, as it was felt that this alignment was not critical. A double convex lens of focal length 5.3 cm was mounted in the entrance window interior to the cell. It was positioned such that the focal point of the lens was coincident with the center of the pressure cell.

Knowledge of the power density at the focal volume was important throughout the study. Two methods were employed to determine the focal area of the lens, and good agreement was reached in comparison. However, both methods are not exact as will be explained later. The first method was simply to place aluminum foil of thickness 10^{-3} inch at the focus of the lens, and fire the laser. The resulting hole diameter was measured and found to be one mm. This method lacked exactness in that the outer dimensions of the hole are most probably a result of melting rather than the "burning" effects at the center. The second method involved production of a plasma in hydrogen gas as a result of optical breakdown. The gas was set to a low presure and the laser fired as the pressure was gradually increased. One such shot resulted in which the forward transmitted pulse was similar to the laser pulse except for small distortions at the top of the pulse. This was taken to be very close to the threshold of breakdown. The pulse power, and gas pressure were recorded. The data in reference one was consulted,and the focal diameter computed with this

information. The power density at the focus of the lens is given by

$$F = P/A$$

where P is the power of the laser pulse, and A is the area of the focal volume in crossection. The pressure of the hydrogen gas was 2.5 psia, or 0.17 atm. Figure 5.5 of Ref. 1 was extrapolated for this low pressure, and the corresponding power density is 8×10^{11} W/cm^2. The power of the laser shot was 299 MW. When these values are substituted in the above formula, the result is

$$A = 37.4 \times 10^{-6} \text{ cm}^2.$$

The focal area is taken to be that of a circle, and the corrresponding diameter is 0.07 mm. It should be mentioned here that the sources of the book [Ref. 1] did not agree in their respective measurements of breakdown threshold in that each incorporated different techniques for focal spot diameter measurement. One of these methods involves use of the equation

$$D = f\theta$$

where D is the focal spot diameter, f is the lens focal length, and θ is the laser beam divergence. The Korad laser

manual was consulted for the laser beam divergence. The published divergence is 1.7 x 10^{-3} radians. Using the above formula, with a focal length of 5.3 cm, and the published divergence results in a diameter of 0.09 mm, which is in good agreement with the threshold criteria measurement, a focal diameter of 0.09 mm was used in computations of power densities in this study.

The laser pulse monitor was arranged such that it received a sample of the laser pulse before breakdown with the aid of a 4% beam splitter. Light from the beam splitter was directed to a magnesium oxide diffuser block, and then received by the detector from the diffuser block. A diffuser block was necessary in two applications of the experiment in order to reduce the possibility of detector damage. The K-D1 detector had an internal integrating circuit. Output from this circuit was displayed on a Tektronix 564B storage oscilloscope. The calibration of this arrangement was carried out by Leslie McKee in a previous work, and his calibration chart was utilized throughout this study.

A magnesium oxide diffuser block was also placed directly in front of the exit window of the cell. The forward transmitted light detector was situated to receive its light from this diffuser block. A narrow band pass filter of 35 angstrons half-width, centered at the laser wavelength was placed in front of the detector. Calibration of this arrangement was not needed, as relative measurements of the forward

transmitted light were made. Signals from this detector were fed to a Tektronix 7904 oscilloscope, and photographs of the resulting wave form were made.

The photodiode placed at the side window was connected to an integrating circuit, and its signal was also displayed on the Tektronix 564B storage scope. It was necessary to operate the oscilloscope in the chop mode in order to present two traces (the other from the laser pulse monitor) simultaneously. This afforded plasma radiation information in arbitrary energy units. Again calibration of this arrangement was not accomplished, as relative energies were considered sufficient. On occasion this detector was also used to obtain plasma radiation intensity information.

IV. DATA

Initially it was necessary to obtain some general information concerning absorption characteristics of a hydrogen plasma as a function of hydrogen gas pressure. The output from the forward transmitted light detector was connected to a Tektronix 7904 oscilloscope, and photographs of the pulse forms were taken. Hydrogen gas pressure in the cell was reduced to 20 microns of mercury, and the laser fired. The resulting photograph of the wave form was used as a "no absorption" standard for comparison.

At this point it is necessary to point out the two possible methods of pulse comparison. The first involves taking a picture of the laser pulse before breakdown, and taking another picture of the same pulse after breakdown. This method requires two independent oscilloscopes, and a calibration to compensate for the differences in horizontal and vertical scales of the two oscilloscopes in order to make direct comparison between the two pulses. The second method requires only one oscilloscope; in that a picture of a given pulse was compared with the picture of a pulse in which breakdown was not encountered. Both of these pulse pictures were obtained from an oscilloscope receiving its signal from the forward transmitted light detector.

The second method was chosen as it was found that the vertical scale calibration between the two oscilloscopes was unreliable in that some of the points on the calibration

chart were three to five volts from the best straight line through the points. This would represent an error of 20% at medium to high intensities. Compensation for slight deviations in laser energy was accomplished with the use of a scale factor, E_s/E. Where E_s is the energy of the laser shot designated as the standard, and E is the energy of the shot to be compared. This method was successful in that errors of only three percent were experienced on the average.

The pressure in the cell was increased from shot to shot up to 900 psig. It was assumed that the first shot at the low pressure of 20 millitorr did not experience breakdown as no signal was received from the detector at a side window. The intensities of the higher pressure shots were measured directly from the photographs at the time of the standard pulse peak. This time did not in general coincide with the peak of the pulse after breakdown. Time jitter in the oscilloscope was less than one nanosecond. These measurements were compared to the standard pulse in the following way. The measured intensity was divided by the standard pulse intensity, and this quantity was multiplied by the scaling factor mentioned above. This equation

$$I_r = E_s/E \times I/I_s$$

yields the relative intensity transmitted through the plasma, where E_s/E is the scale factor discussed above, I is the

intensity of the forward scattered pulse at the time of measurement, and I_s is the intensity of the laser pulse that did not experience breakdown, measured at the same pulse time as I. Figure 2 is the result of these measurements.

It can be seen [Fig. 2] that the absorption at laser pulse peak time increases rapidly up to 30 psia, and then is relatively constant up to 415 psia. Measurements beyond 415 psia and up to 915 psia show no significant change from this constant level.

In another phase of the study, the energy of the plasma radiation was measured as the pressure of the hydrogen gas was varied. The signal from the side window was integrated and displayed on a memory oscilloscope. The height of the oscilloscope trace from the zero line at time zero was proportional to the energy of the plasma radiation. These deflections were recorded and scaled in the same way with the scale factor mentioned before. However, in this case the standard energy was chosen to be that of the laser pulse which produced the smallest non-zero oscilloscope trace deflection. These measurements are shown in Figure 3.

One aspect apparent in comparing the two graphs is the difference in the trends of each after 30 psia. The energy plot has a relatively slow decay after 30 psia, whereas the relative intensity curve remains constant after 30 psia. If it is assumed that higher absorption would produce higher plasma radiation energy, then one would question the

decrease in plasma radiation energy at higher pressures while according to Figure 2 the absorption remains constant in the same pressure range.

A possible explanation is that there is a frequency shift in the laser light during passage through the plasma. This light might then be filtered out by the narrow band filter used on the forward transmitted light detector, and subsequent measurements would indicate higher than actual absorption.

Some evidence for a frequency shift was sought in the following manner. The pressure cell was filled with hydrogen at a pressure of 22 psia where the probability for breakdown was high. Pictures of the breakdown pulse were obtained in the manner described before, and then again without the narrow filter in place. The photographs indicated that much more light was present at the detector when the filter was not used. The pulse forms had increased in intensity only during the time of the original pulse. There was no indication of light at times beyond the original pulse termination. This excludes the possibility that the increase might be due to the bremsstrahlung, and hydrogen line radiation from the plasma. Intensity pulses of the plasma radiation were photographed and they were much longer in time, and much reduced in intensity compared to the intensities of the laser pulse and the forward scattered pulses. There is a possibility that the filter used simply reduced the intensity of the center laser wavelength. This filtering

should then be constant in percentage regardless of the intensity of the incident light. Preliminary measurements showed that this was not the case, and no predictable pattern was evident. The half-width of the filter used is 35 angstroms. Frequency shifts as a result of thermal doppler broadening have been reported [Ref. 6]. These were approximately three angstroms wide, corresponding to temperature estimates between one and ten ev. The conclusion here is that evidence for a much larger frequency shift is present, but not necessarily attributed to thermal broadening.

In order to discover evidence of anomalous absorption, the forward scattered light pulses were compared in time with the very low pressure pulse used as a "no absorption" standard. Here each pulse was compared with the standard in corresponding four nanosecond increments. Inherent in these measurements is the possibility of frequency shift, and no attempt was undertaken to exclude its possible effects. Figures four through eight are the result of these measurements. Straight lines were drawn between points on the graphs only to aid the reader in keeping track of a specific intensity profile. In some cases these lines do not accurately show the trend, as fine structure was observed in some cases. In general the fine structure of the photographs and subsequent fine measurements if employed are damped out by the rather coarse, but accurate measurements utilized.

Three characteristics are apparent. In the cases of low pressure the absorption is weak and with maximum generally at the laser pulse peak, and a return to 100% transmission near the end of the laser pulse. At high pressure apparent absorption is more severe at all times than the lower pressures, and breakdown characterized by the onset of absorption, occurs earlier in the laser pulse. Finally there is some cyclic absorption more apparent in the lower pressures. The most interesting cases occur in the curves of 5.3 and 8.7 psia. In these cases apparent absorption has decreased significantly at times close to the laser peak. In the curves of 7.3 and 14.7 psia, as shown in Figure 5, there is an interesting occurance in that each curve has a significant increase in absorption after a period of relatively constant absorption. This might be due to an instability, causing anomalous absorption at these lower pressures.

Many shots were performed at pressures close to the pressure predicted in the theory for anomalous absorption. The resulting curves of relative intensity did not differ significantly from pressures 100 psi less than, or greater than the predicted pressure. One such curve is furnished in Figure seven, in the case of 289 psia.

Hand tracings of some of the forward scattered pulses are provided in Figures ten through 12. Hand tracing was necessary as the photographs were too dim for reproduction. They are arranged in order of increasing pressure. These

pulses were obtained on separate days, and should be compared cautiously, as the laser pulse-width was not exactly the same from day to day. Variations of two to four nanoseconds were experienced in the laser pulse-width from one day to the next. Some general characteristics are apparent, and are discussed. Notice also that the scale factor of the tracings is decreased by a factor of ten at pressures greater than one atmosphere. This was necessary in order to more clearly define the pulses.

Generally the absorption trend is dramatic from low pressures up to 25 psia. The trend from that point up to 915 psia is relatively stable with a slight decrease in absorption, as evidenced by the higher peaks of the pulses. Another characteristic apparent is the rather smooth, and well defined peaks at low pressures, and again at high pressures. In comparison the peaks of the pulses in the range from 22 psia to 35 psia are relatively ragged. At higher pressures the peaks tend to smooth out, and become more sharply defined. It must be mentioned that the smoother peaks at pressures less than 22 psia are somewhat deceiving, in that a less sensitive scale factor was used at these pressures. It was, however, necessary as the peaks would have been off scale if the more sensitive scale factor were used at the pressures lower than one atmosphere.

V. RECOMMENDATION

It is necessary that the possibility of frequency shift of the laser light be explored further, in order that greater accuracy in absorption may be obtained. The graphs of Figures two, and five through eight indicate high absorption at high pressures, yet Figure three indicates appreciably lower energy of plasma radiation at these pressures. If a thorough study of frequency shift is undertaken, it might clarify the apparent discrepancy.

Two other steps in experimental technique are recommended. A method to detect reflected laser light from the plasma at 180° should be incorporated. This also might account for the apparent increased absorption, and in turn would more thoroughly account for the total energy distribution of the laser beam. The second step is simply to place light gathering optics between the plasma radiation detector and the cell window in order to collect more of the radiation energy. If the point of breakdown shifts, the plasma might then be outside of the limited light acceptance angle of the detector. The resulting signal from the detector would be misleading if it was assumed that the detector was viewing the plasma.

In the curve of Figure 3 one notices the scattering of points at the peak in the range between 20 and 60 psia. This spread in points might be due to an instability in which

absorption characteristics are not readily reproducible. This region of pressures warrants closer study.

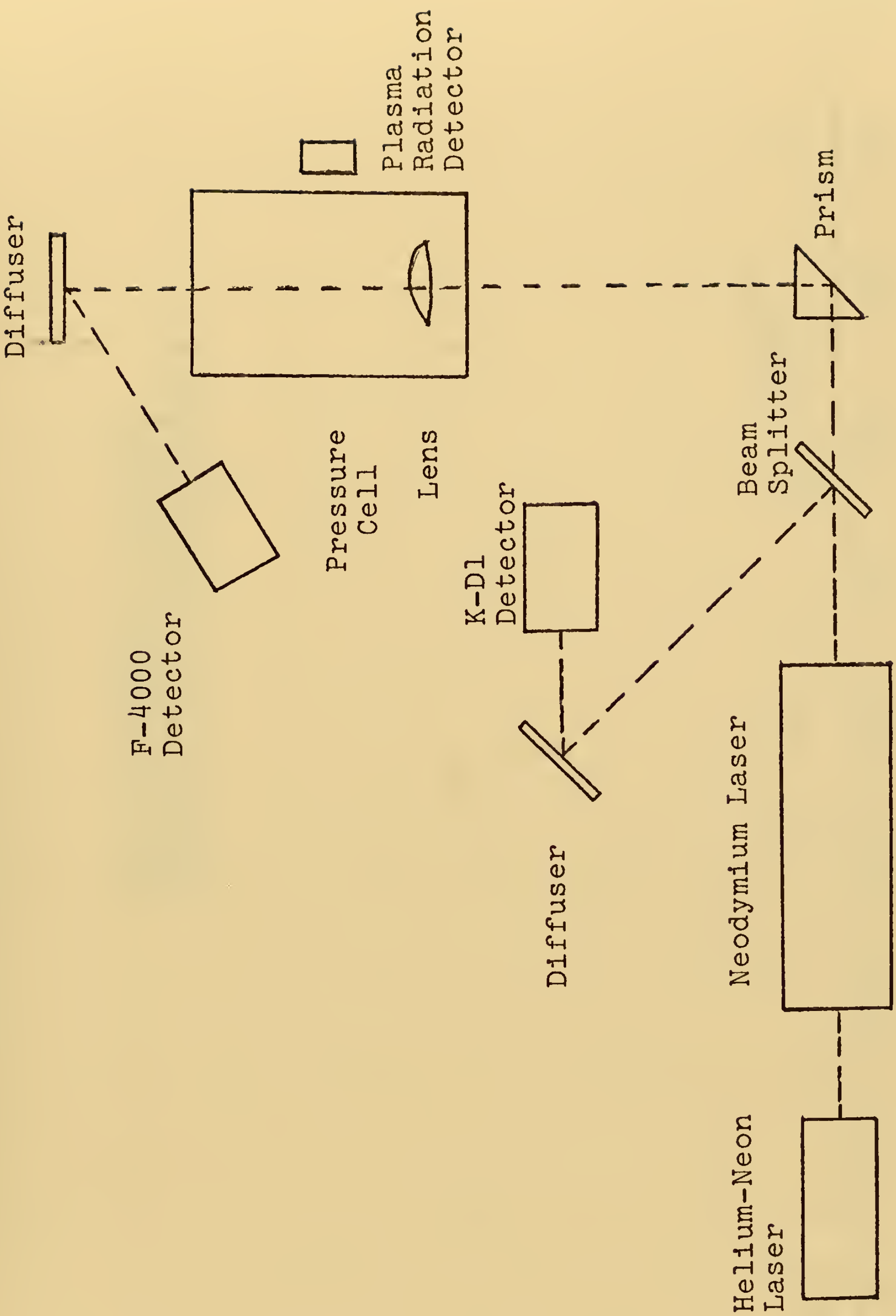
Diffuser
Plasma Radiation Detector
Pressure Cell
Lens
F-4000 Detector
K-D1 Detector
Beam Splitter
Prism
Diffuser
Neodymium Laser
Helium-Neon Laser

FIGURE 1

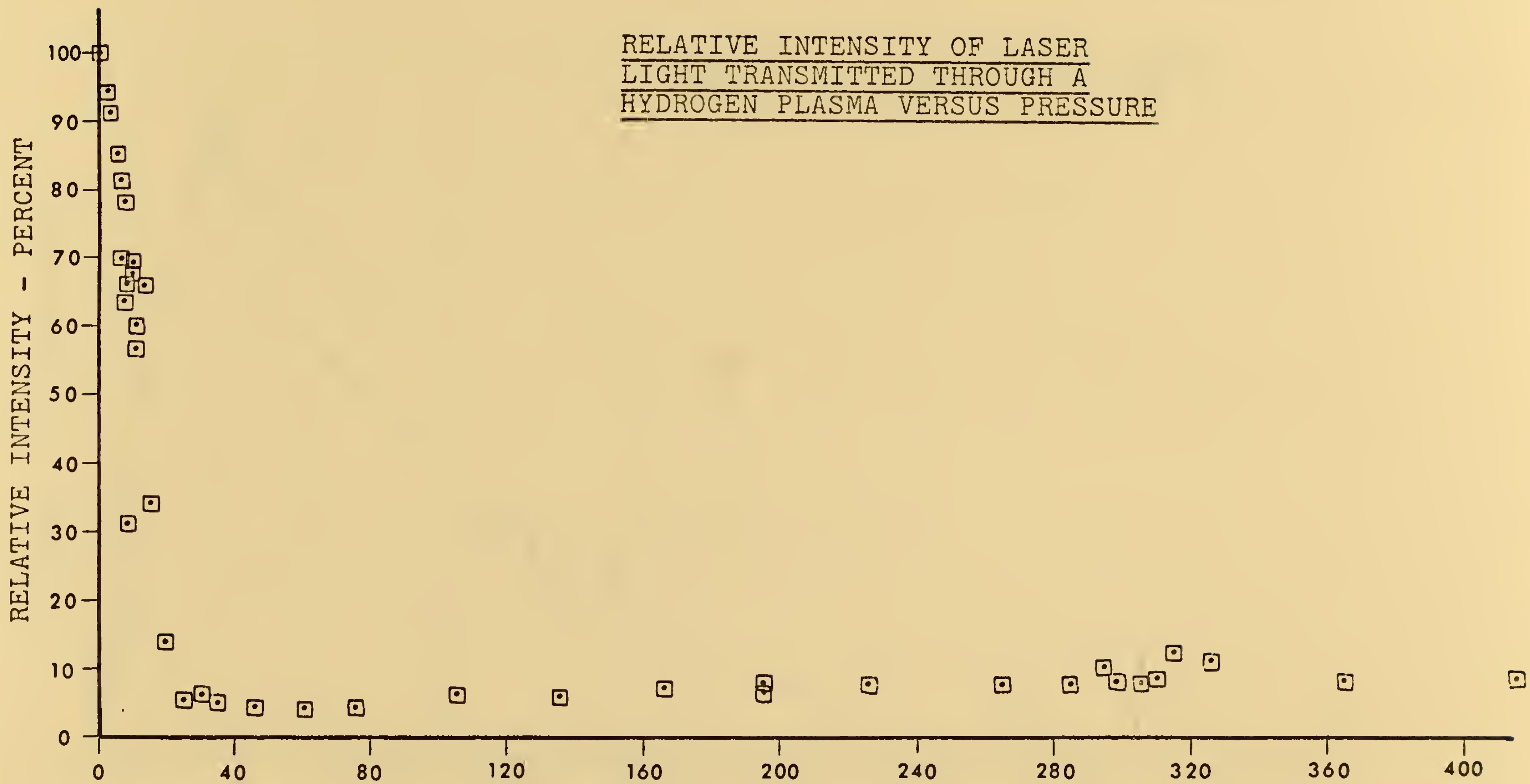
RELATIVE INTENSITY OF LASER
LIGHT TRANSMITTED THROUGH A
HYDROGEN PLASMA VERSUS PRESSURE
RELATIVE INTENSITY - PERCENT
0
10
20
30
40
50
60
70
80
90
100
0
40
80
120
160
200
240
280
320
360
400
PRESSURE - PSIA

FIGURE 2

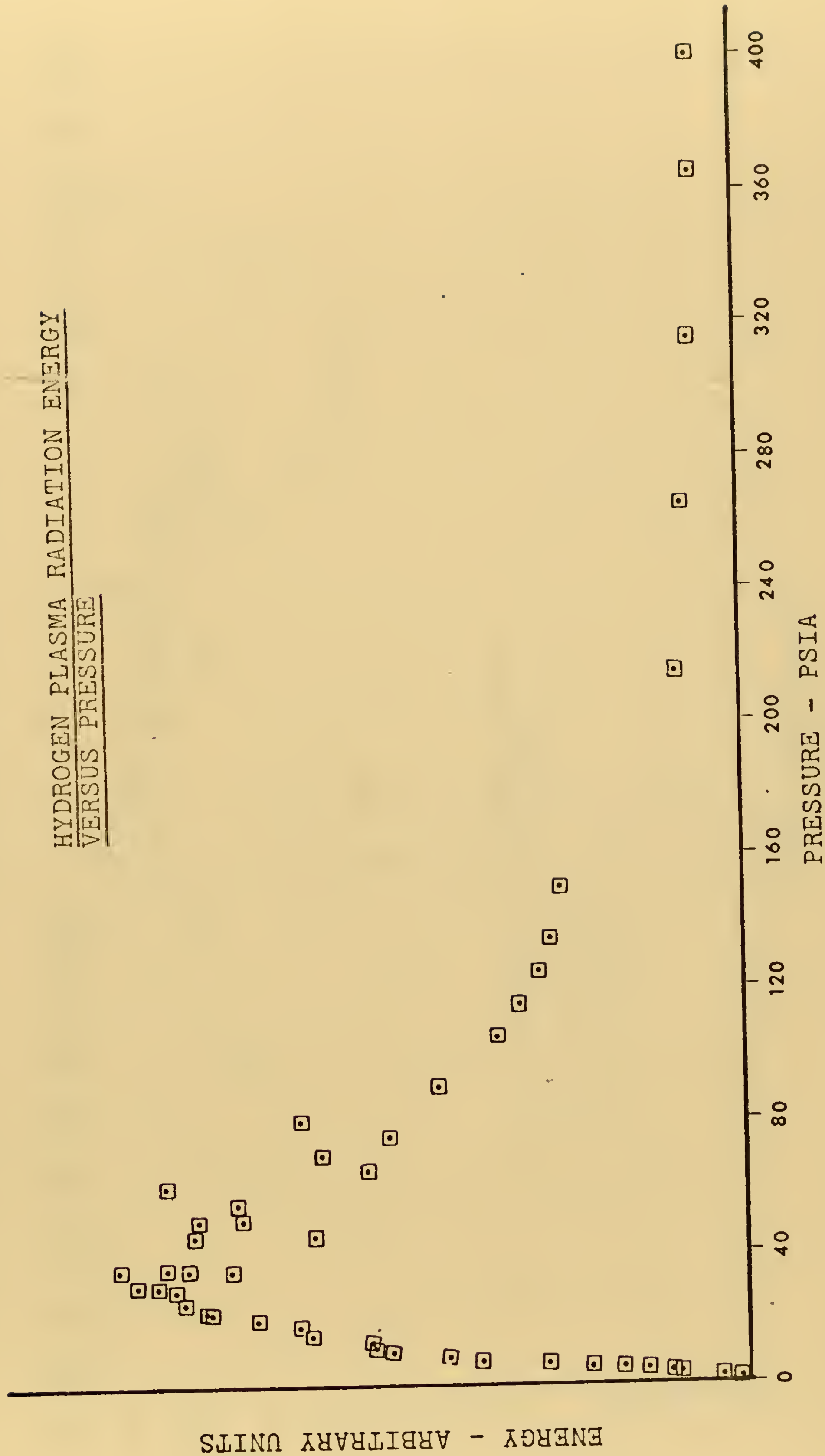
HYDROGEN PLASMA RADIATION ENERGY
VERSUS PRESSURE
ENERGY - ARBITRARY UNITS
PRESSURE - PSIA
0
40
80
120
160
200
240
280
320
360
400

FIGURE 3

TIME HISTORY OF RELATIVE LASER LIGHT INTENSITY TRANSMITTED THROUGH A HYDROGEN PLASMA

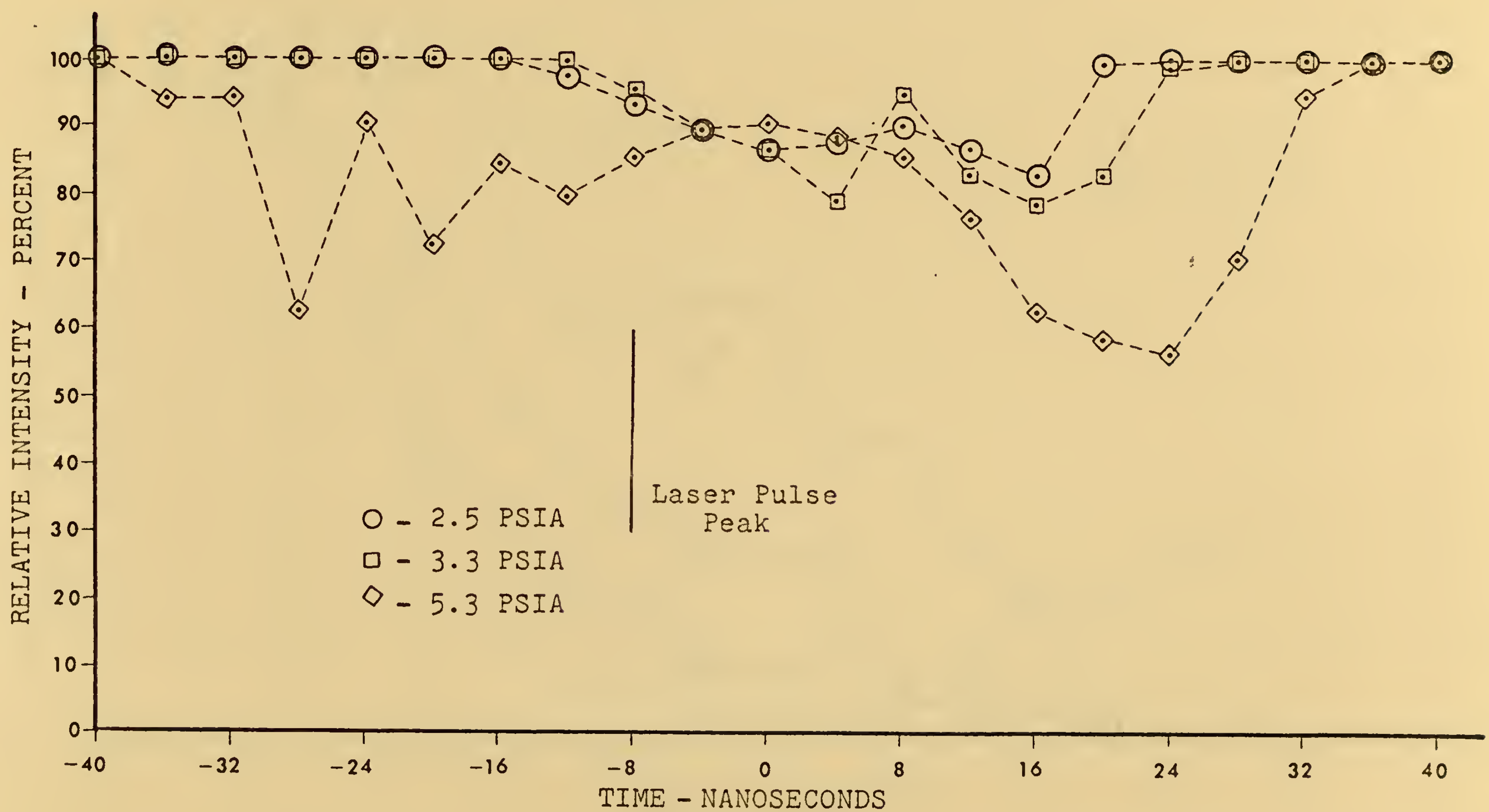

FIGURE 4

TIME HISTORY OF RELATIVE LASER LIGHT INTENSITY TRANSMITTED THROUGH A HYDROGEN PLASMA

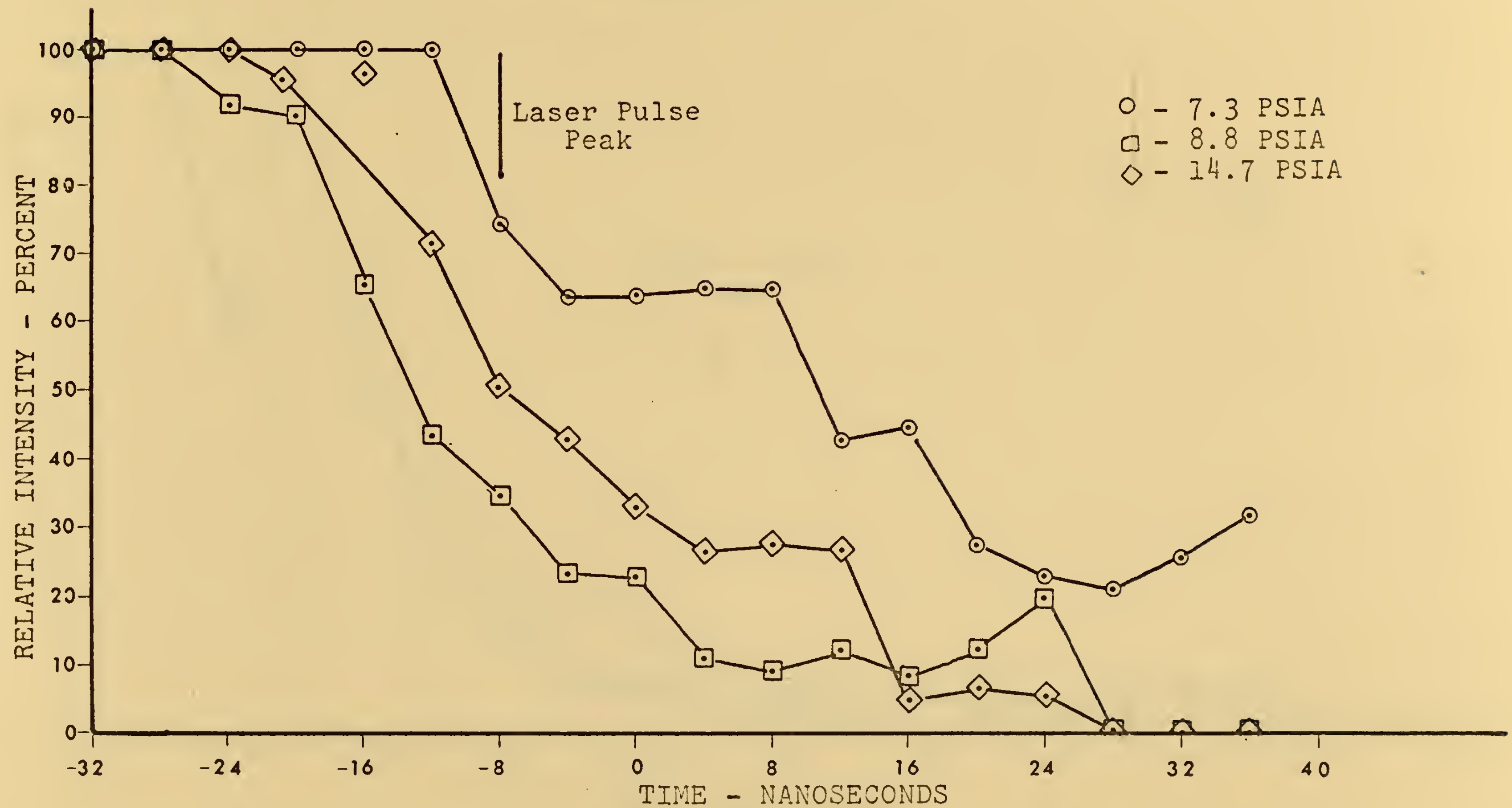

FIGURE 5

TIME HISTORY OF RELATIVE LASER LIGHT INTENSITY TRANSMITTED THROUGH A HYDROGEN PLASMA

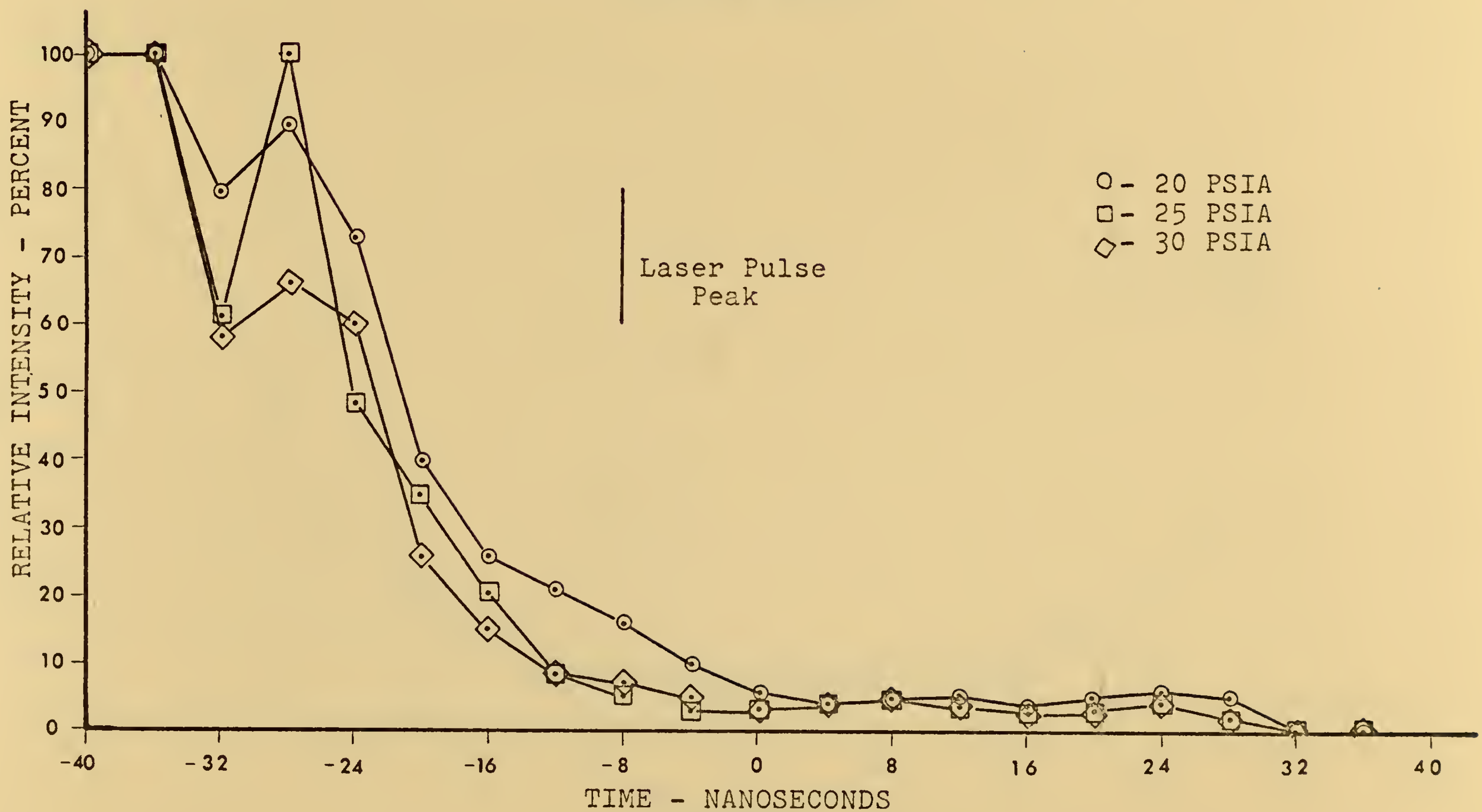

FIGURE 6

TIME HISTORY OF RELATIVE LASER LIGHT INTENSITY TRANSMITTED THROUGH A HYDROGEN PLASMA

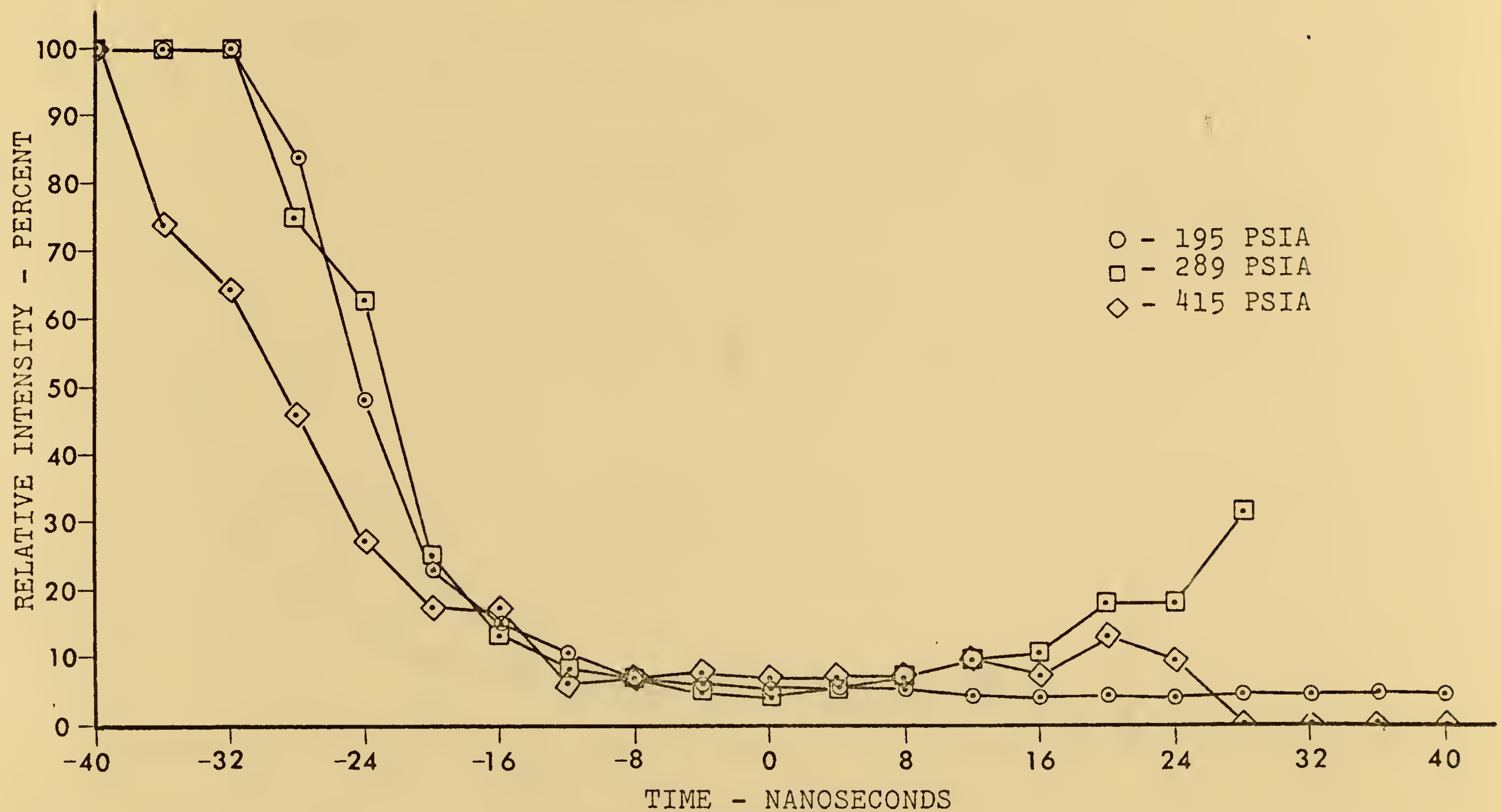

FIGURE 7

<u>TIME HISTORY OF RELATIVE LASER LIGHT INTENSITY TRANSMITTED THROUGH A HYDROGEN PLASMA</u>

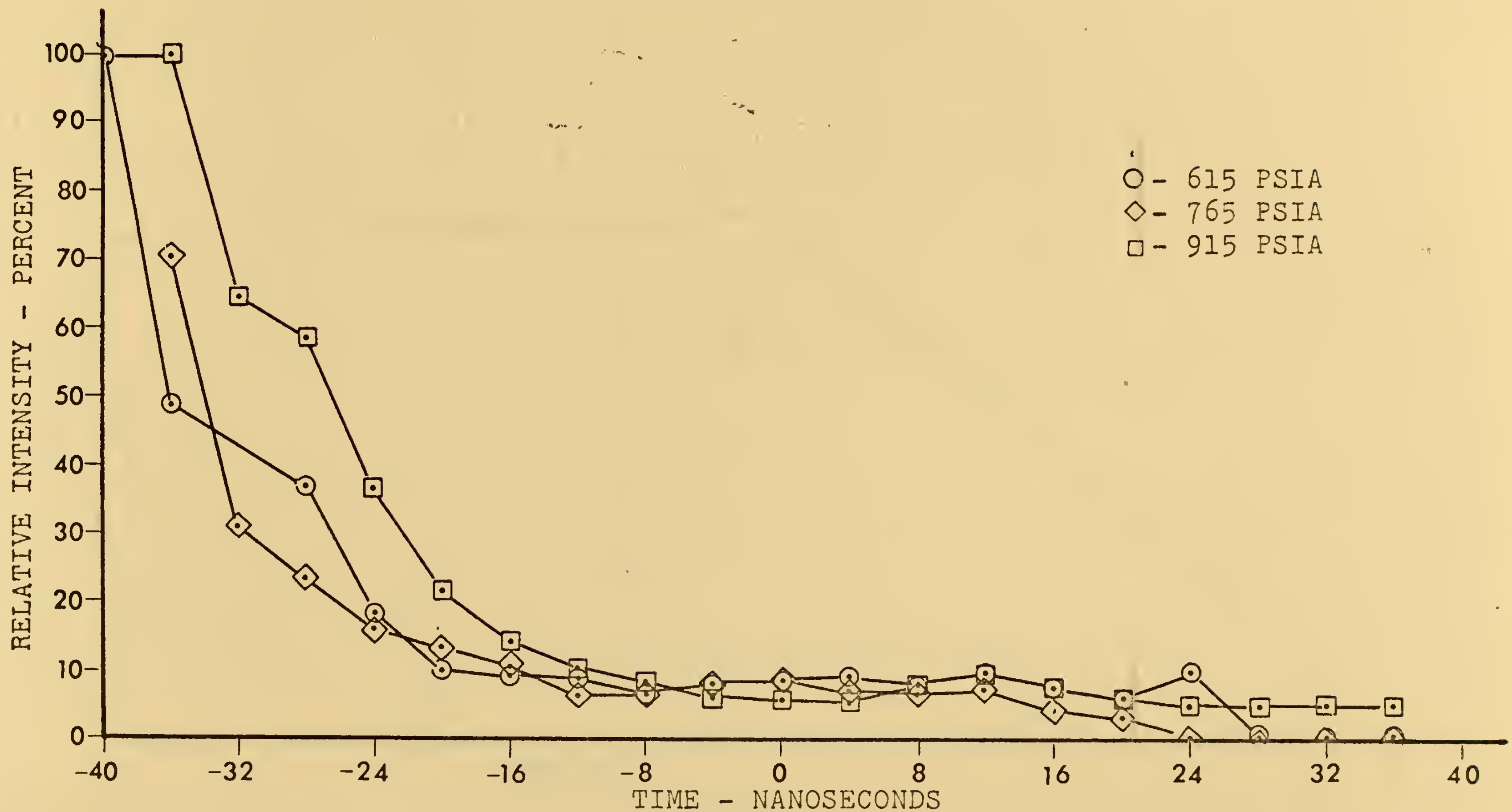

FIGURE 8

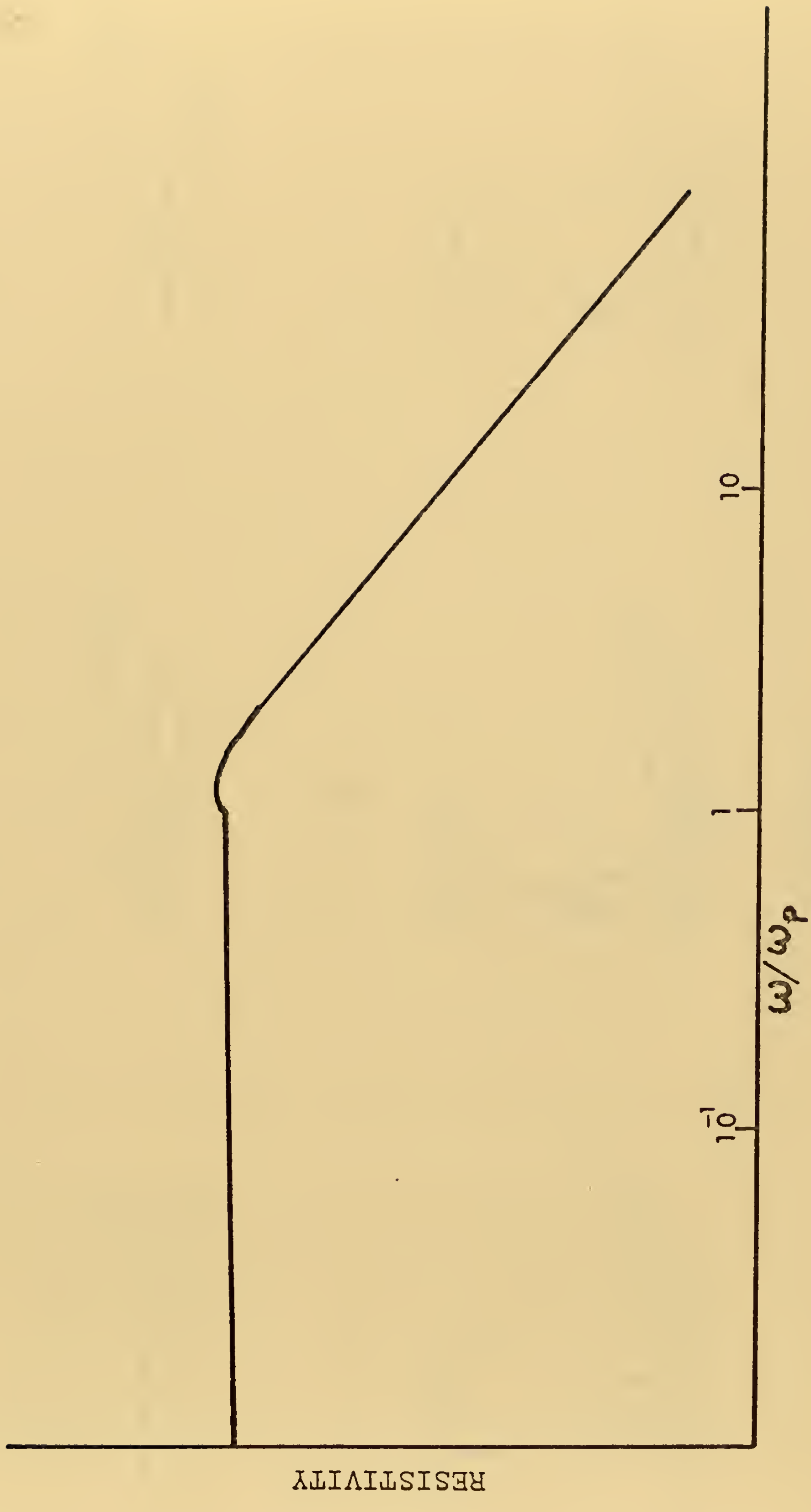

FIGURE 9

FORWARD TRANSMITTED PULSES AT VARIOUS PRESSURES

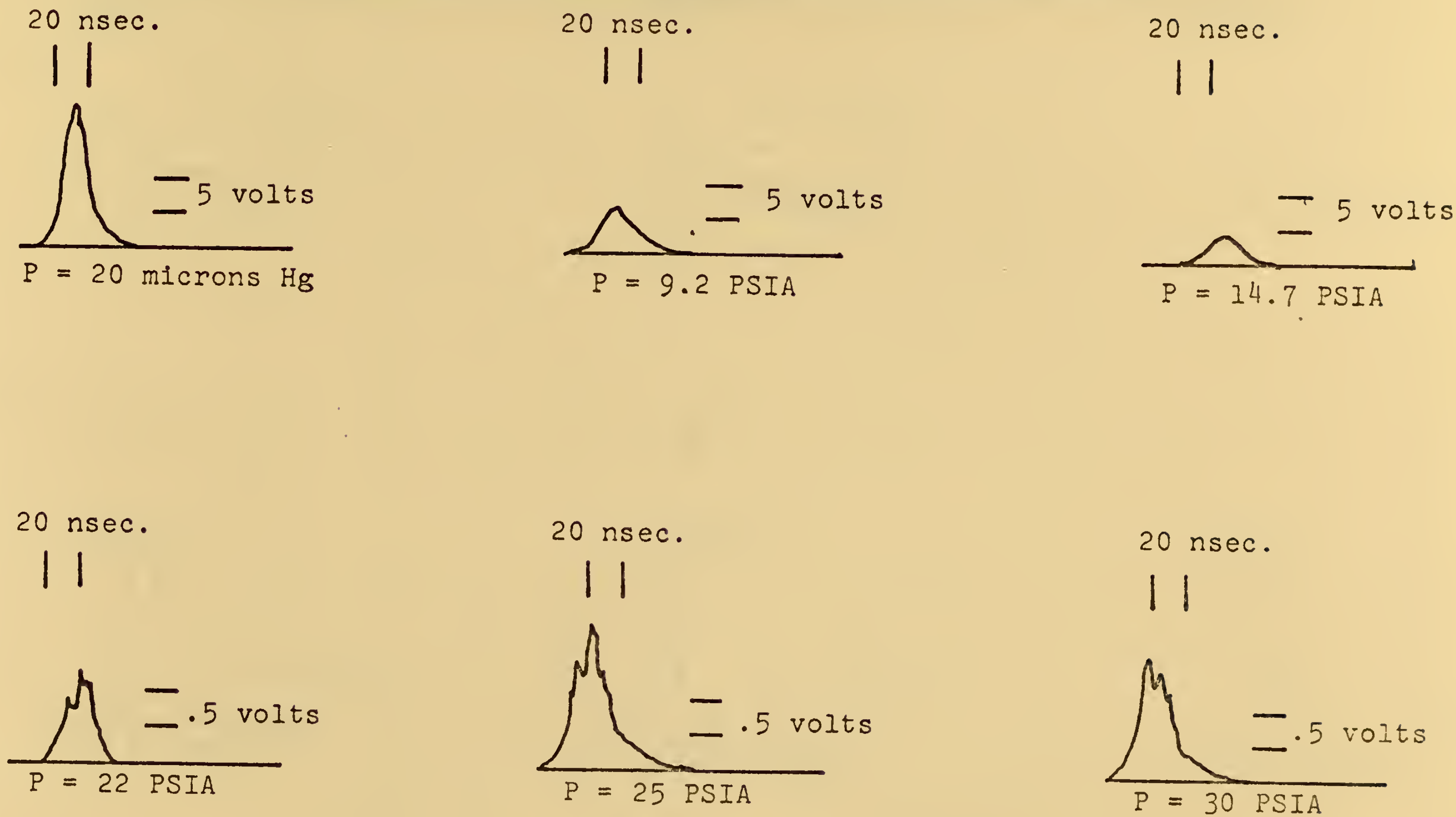

FIGURE 10

FORWARD TRANSMITTED PULSES AT VARIOUS PRESSURES

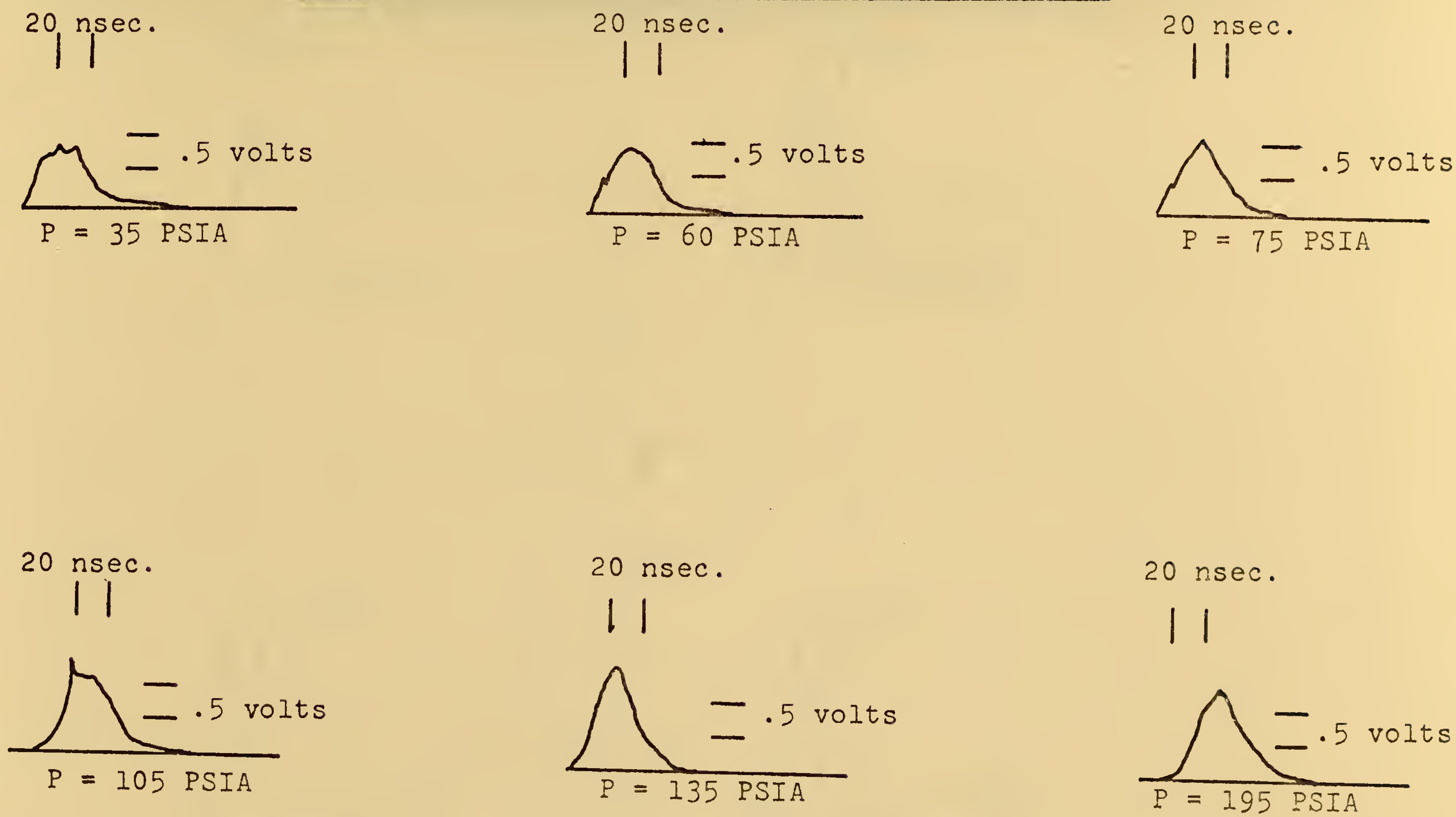

FIGURE 11

FORWARD TRANSMITTED PULSES AT VARIOUS PRESSURES

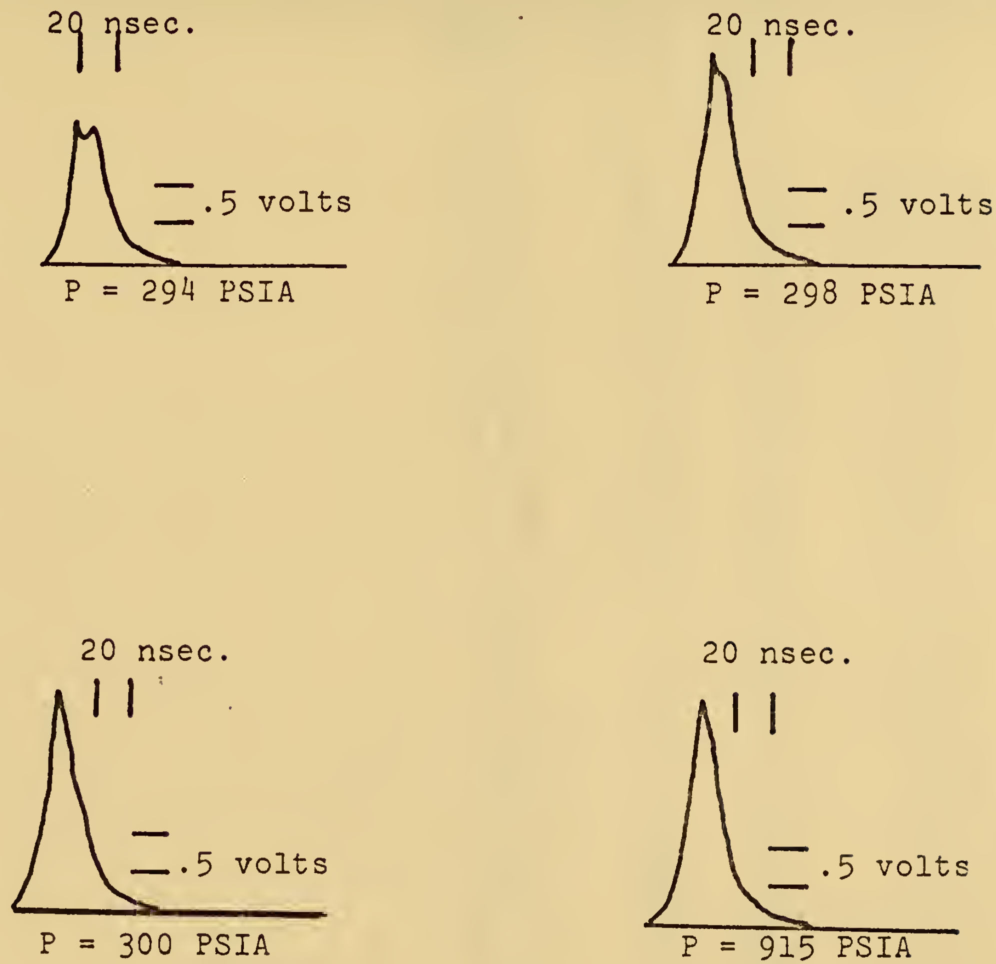

FIGURE 12

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Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

ORIGINATING ACTIVITY (Corporate author) Naval Postgraduate School Monterey, California	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

REPORT TITLE

Laser Light Absorption Characteristics of a Laser Produced Hydrogen Plasma

DESCRIPTIVE NOTES (Type of report and, inclusive dates)

Master's Thesis; December 1972

AUTHOR(S) (First name, middle initial, last name)

James Allen Carlisle

REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
December 1972	42	6

CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
PROJECT NO.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Naval Postgraduate School Monterey, California 93940

ABSTRACT

Light from a neodymium doped glass laser was focused in Hydrogen gas at pressures from 20 millitorr to 62 atmospheres in order to produce optical breakdown of the gas. In the cases where breakdown was experienced, absorption of the remainder of the laser pulse by the resulting plasma was studied. It was found that the hydrogen plasma had some very distinct absorption characteristics; in that, absorption was very small at pressures slightly exceeding the threshold for optical breakdown, and very strong at pressures above one atmosphere. There was strong evidence of a frequency shift greater than 35 angstroms of the laser light as a result of its transit through the plasma. Photographs of the forward transmitted laser intensity pulses after breakdown were compared in time with a similar pulse in which no breakdown was experienced. An effort was made to discover evidence of anomalous absorption at the plasma frequency near the frequency of the laser light. The data does not conclusively support anomalous absorption in the pressure range where the plasma frequency is approximately equal to the laser light frequency. There was evidence of increased absorption at lower pressures that might be a result of an anomalous heating mechanism.

DD FORM 1473 1 NOV 65 (PAGE 1)

S/N 0101-807-6811

Security Classification

A-31408

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Hydrogen Plasma						
Absorption						
Laser						

Thesis
C223 Carlisle 141273
c.1 Laser light absorption characteristics of a laser produced hydrogen plasma.